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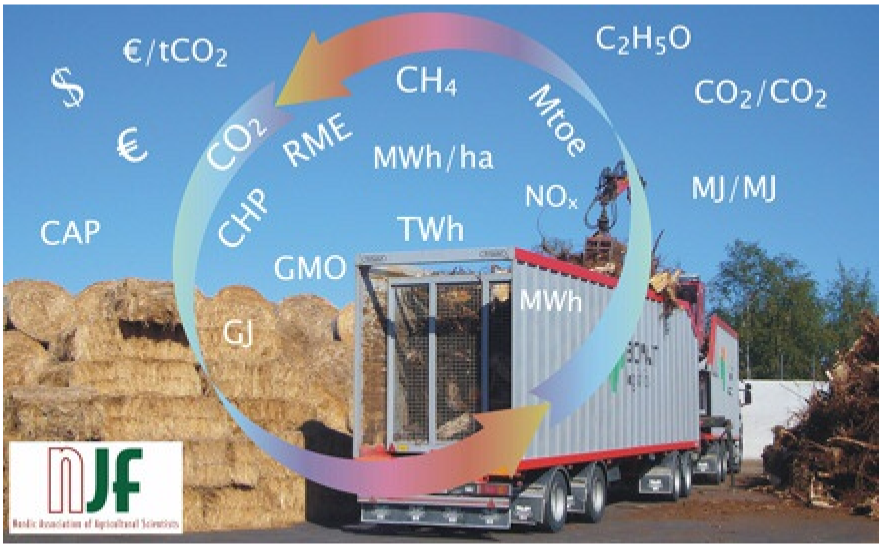

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Digested slurry as a fertilizer for biogas ley

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Introduction

In Finland, economical biogas production on farms requires use of some co-substrate unless the herd is large (Hagström et al., 2005) because there is no extensive subsidies nor legally guaranteed prize for produced electricity (fixed premium scheme) (Kalmari, 2006) like *e.g.* in Germany (BMU, 2007). In Finland most of manure, about 81%, is produced by cows in small herds (Kapuinen, 1994). The proportion of perennial ley used for silage has been rather high in crop rotation because of cheap grain. On cattle farms, grains are often harvested as a whole-crop-cereal-silage to avoid purchase of separate harvesting machinery for silage and ripen grain. Because maize does not grow well in Finnish climate the natural choice for co-substrate production are perennial leys.

The quality of silage for feeding is best made from the primary growth (Huhtanen et al., 2006, 2007). In spring, fertilisation with slurry would risk the quality of silage and the leys do not quite well carry heavy slurry spreading tankers. Moreover, the significance of yield loss of the primary growth is greater than of the re-growths because proportions of yields of each growth depending on species are on an average 42%, 32% and 26% (Tyynelä et al., 2004).The proportion of the yield of the primary growth is the greatest for timothy and the smallest for perennial ryegrass. Therefore, there is a need to spread manure only after the first cut and re-growth needs then to be harvested. A good option for use of re-growths is as a co-substrate of biogas plant if there is no use for that as a feed.

Scientists often claim that the nutrients in digested slurry were more available for plants that those of non-digested slurry. Alkalinity of digested slurry is higher than that of non-digested slurry and it theoretically consists more soluble nitrogen *i.e.* one could assume greater ammonia emissions from digested slurry applied on the surface (Mattila and Joki-Tokola, 2003). To verify these claims there was a field experiment established on a perennial ley of timothy and meadow fescue growing on clay in Jokioinen (23º26,3’, E60º47,9’ N) in 2005 to 2006.

Materials and methods

The ley was fertilized 92 kg N/ha in mineral fertiliser in both the springs. The primary growth and its protein content were measured in the 2nd year but not in the 1st year. The fertilising treatments of 4 blocks were carried out after the first cut in the same way in the same plots in both the years. The levels of main treatment were non-digested and digested slurry. The aim was to apply them in maximum allowed quantities. Therefore, the quantity of non-digested slurry spread was determined to contain tot. N 170 kg/ha (ETY, 1991 and Government, 2000). The targeted rate of sol.

N from digested slurry was the same than from non-digested, about 85 kg/ha. Digested slurry was also applied in terms of total nitrogen, about 85 kg/ha, in case the hypothesis was correct *i.e.* the apparent N levels from digested slurry were too high for comparison. Each treatment was split to half, application with an injector or trailing hoses. In addition there were N levels of 0 to 175 kg N/ha in mineral fertilizer with nutrients in equivalent relations than in the slurries. There was no separate fertilisation for the 3rd growth. The yields and protein content of the 2nd and 3rd growth (post-effect) were measured in both years. The NH_3 emissions were measured for 3 days and N_2O emissions until fertilisation next spring.

Results and discussion

Digestion increased the fertilisation value of slurry according to the raise of proportion of sol. N to tot. N, which decreases the ratio of P to sol. N. This allows for increasing the proportion of slurry in the N fertilisation of ley without exceeding the limit of tot. N from animal manures stated in the nitrate directive (ETY, 1991) and its national implementation (Government, 2000) and the limit of phosphorus in The Finnish Agro-Environmental subsidy scheme (MMM 2007). *E.g.* in 2006 sol. N rates were 97 and 103 kg/ha and K rates 200 and 220 kg/ha from non-digested and digested slurry, respectively, at 170 kg/ha of tot. N. K rates were somewhat too high and might lower uptake of divalent cations and increase the risk of nutritive diseases in bovine. In our strategy, however, the planned use of the re-growths is as a co-substrate.

In 2005 dry matter yield of the 2nd growth increased until N level of 125 kg/ha. Dry matter yield of 3rd growth and of the season increased until N level of 175 kg/ha *i.e.* 267 kg/ha during the season while 240 kg/ha is allowed by the Finnish Agro-Environmental subsidy scheme (MMM, 2007). The excess N for the 2nd growth was used by the 3rd growth. A rate of mineral fertilizer more than 125 kg of sol. N/ha after the 1st cut was not economical.

In case of nutrient composition like ours, about 40 kg/ha of sol. N from mineral fertiliser, could have been used after the 2nd cut in addition to that of slurries at 170 kg/ha of tot. N. The actual rates of sol. N were only 64.9 kg/ha and 72.5 kg/ha in 2005 and 73.9 kg/ha and 77.2 in 2006 from non-digested and digested slurries, respectively, because the results of pre-analyses were higher than the final ones. Anyway, even digested slurry could not cover the optimum rate of sol. N for even the 2nd growth but only about 100 kg/ha and the remainder needs to be applied in mineral fertiliser.

The ammonia emissions from slurry applied on surface can be 30 to 40% of sol. N for untreated and 60% for treated like aerated slurries (Mattila and Joki-Tokola, 2003 and Mattila et al., 2003). In 2005 the yields of the 2nd growth corresponded with those of N levels at the remaining quantities of sol. N after the apparent ammonia emission. Sol. N of slurry produced a significantly 29% smaller dry matter yield in the 2nd growth than that of mineral fertilisers when slurry was not digested but injected. The variation in smaller re-growth was greater than in the primary growth and therefore the significant differences were rather large. Hence, measured but not significant loss of dry matter yield was 14% of the yield produced with mineral fertiliser when digested slurry was injected. Bandspread non-digested and digested slurries yielded 17% (n.s.) and 20% ($p<.05$) less than mineral fertilizer. The ammonia emissions of injected treatments are marginal (Mattila and Joki-Tokola 2003). The low yields of injected but non-digested slurry must be result of same negative processes in soil.

The 2nd growth fertilised with digested slurry injected produced slightly but not significantly lower yield than sol. N of mineral fertiliser. Digestion allows for use somewhat more slurry to compensate the tendency of smaller yield produced in the 2nd growth with sol. N of slurry at rate of 170 kg/ha of tot. N, *i.e.* similar dry matter yields are possible to reach using somewhat more digested slurry injected.

Supplement N from mineral fertilizer is required to produce feed unless the slurry is digested because non-digested slurry as a sole fertiliser resulted in a lower protein content of 9.0 to 9.5% than normal 12.7% at 75 kg/ha of N from mineral fertiliser. A normal level of 11.2 to 13.2% was achieved by using digested slurry. Digestion increased protein content by 2.3%-units and injection 0.8%-units. Injection and digestion had positive interaction in the protein content. Combination of digestion and injection increased the protein content by 3.6%-units.

When non-digested slurry was injected the apparent utilisation of sol. N was very low, only 10% when similar values for digested and injected slurry (50.0%) and mineral fertiliser (54.6%) were true. Even digestion without injection improved N utilisation significantly from 17.7 to 32.0%. The protein yield was similar in treatments with injected and digested slurry and equivalent rate of sol. N in mineral fertilizer. Injection of non-digested instead of digested slurry lowered the crude protein yield of the 2nd and 3rd growth.

In 2005 dry matter yield of the 2nd growth increased till level of 125 N kg/ha and protein content till level of 175 N kg/ha. There is no need to increase the protein content more than what is reached at level of 100 kg N/ha. Because 60% or less of sol. N in slurry is comparable to that of a mineral fertilizer unless digested and injected an extensive use of slurry in other cases cuts down the dry matter yield in allowed rates in the Finnish Agro-environmental subsidy scheme (MMM 2007).

In 2005 the 3rd growth was rather small, less than 1 t/ha of dry matter. It is questionable if it is worthwhile to harvest. When digested and injected (20%, n.s) and bandspread non-digested slurry (12%, n.s.) was greater than equivalent N level. As a result of this the combined dry matter yield of 2nd and 3rd growth produced with slurry digested and injected was only 10.6%, digested and bandspread 13.7%, non-digested and bandspread 16.2% but non-digested and injected as much as 30% smaller than that produced with mineral fertilizer. The loss in dry matter yield of season would be about 60% of those. The fertilisation value of digested slurry applied according to its sol. N content in terms of dry matter yield was almost the same than that of mineral fertiliser when injected and when the ley was cut three times. In this case only non-digested and injected slurry performed significantly worse than mineral fertiliser and other treatments with slurry. Three cuts would not be feasible in Northern Finland.

The protein contents of the 3rd growth in 2005 were 13.2 to 15.0%. Protein yield of digested and injected slurry was significantly (39.7%) better than that of mineral fertiliser. A large rate (175 kg/ha) of N as mineral fertiliser after the first cut did not produce much greater 3rd growth but one could expect that the remainder of the maximum allowed rate of N for 3 growths from mineral fertilizer after the 1st cut in addition to the maximum rate of slurry would produce a 2nd growth equivalent to one produced with 100 kg N/ha from mineral fertiliser in case slurry were non-digested.

The apparent utilisation of sol. N by the 2nd and 3rd growth, 18.3%, was for non-digested and injected slurry significantly less than for digested and injected slurry (63.4%) and for mineral fertiliser (61.7%). For bandspread non-digested slurry it was 26.8% and for bandspread digested slurry 41.0%. They were significantly different and they differed from the one of mineral fertiliser significantly as well.

In 2006 the dry matter yield of the 1st cut was quite normal or rather great, on an average 5365 kg/ha. It contained on an average 15 kg/ha of nitrogen more than was applied in the spring. High N levels in 2005 and use of slurry in any other way than non-digested and bandspread tended to increase the 1st growth in 2006. A cow produces about 100 kg total nitrogen in manure annually (FME, 2002). Therefore a field area of at least 0.59 ha/cow is required for application (ETY, 1991, Government, 2000). Such a field area could produce 3155 kg of dry matter containing 2967 feed units (equivalent with production effect of 1 kg of barley). A cow weighing 500 kg could produce 7040 kg energy corrected milk and a calf a year when 55% of energy of feed originates from concentrates (MTT, 2006). Assuming in-house feeding round the year the first growth in addition to the concentrates is sufficient for the roughage and the 2nd and 3rd growth could be used for other purposes.

The 2nd growth was very small because after the fertiliser treatments there was a severe drought. The dry matter yields of the 2nd cut of slurry treatments were only 588 to 1022 kg/ha, 10.4 to 19.2% of the yields of the 1st cut. In 2005 they were on an average 2926 kg/ha. Non-digested slurry did not produce any contribution in the 2nd growth. At N level 75 kg/ha the dry matter yield was also only 832 kg/ha *i.e.* the effect of the drought was not greater in the slurry treatments than in the mineral fertiliser treatments in the 2nd growth. Non-digested slurry produced a 2nd growth which contained less N than non-fertilised treatment. Because of the exceptional weather conditions no general conclusions can be made of the material of year 2006.

However, although the N of bandspread slurry was not used by the 2nd growth, neither it was used by the 3rd growth because the dry matter yield was about the same than in 2005. Bandspread slurry performed much worse in the 3rd growth in drought than mineral fertilisers. The dry matter yields of the 3rd growth of the N levels fertilised with mineral fertiliser were about double to that of 2005. N of slurry, unless injected, seems not to remain available for the ley as long as for the 3rd growth of the same season. The injected treatments produced significantly 26.3% greater dry matter yield, 40.3% greater protein yield and 84,5% greater apparent N utilisation than the surface applied treatments. The proportion of the 3rd growth in the slurry treatments was on an average only 11.7% of the dry matter yield of the season *i.e.* the differences have hardly any economical significance in practice.

However, evaluating the sum of last two growths, digestion yielded significantly dry matter 26.8% and protein 45.4% more and injection had no negative impact even in a very dry season. The bad performance of injected slurry was compensated in the 3rd growth and the better performance of digested slurry in both the growths dominated in the sum of both the growths. Digestion improved the apparent N utilisation in slurry treatments to the level of that in the mineral fertiliser treatment, which was more than 5 times better than that of non-digested slurry. Even in then the apparent N utilisation was only about 22% when 62% was true for the sum of the 2nd and 3rd cut in 2005. If slurry is injected before severe drought after the 1st cut it is important to harvest the 3rd growth as well.

Injection reduced drastically ammonia emission and eventually odour nuisance and leaching of soluble phosphorus from the surface of leys resulting significant environmental advantages. However, injection increased nitrous oxide emissions.

Digestion reduced the number of hygiene indicators in slurry, Enterobacteria and faecal spreptococci somewhat. The number of enterobacteria, faecal streptococci and coliforms in soil was increased one week after the treatments with non-digested slurry in 2005. In 2006 there were no differences between the slurries and number of enterobacteria and coliforms was high even 3 weeks after the treatments. No effects were found in samples taken from the growth.

Nitrous oxide emissions were greatest just after the application. Another peak in emissions was found in the spring during the snow melt. The cumulative emissions from slurries were no greater than from mineral fertiliser.

Conclusions

In Finland, in spring, the soil is still too wet to use heavy slurry application equipments when the leys should be fertilised. Therefore the fertilisation for the yield of primary growth is most prudent to apply as mineral fertiliser containing no phosphorus because the equipments to apply mineral fertiliser are lighter than slurry tankers. The nitrogen of spring fertilisation is used more efficiently than that of later applications. A part of nitrogen fertilisation, at least 140 kg/ha, needs to be applied as mineral fertilizer anyway because the maximum N fertilisation of ley is 240 kg/ha and the maximum rate of tot. N from manure is 170 kg/ha and only somewhat more than a half of nitrogen in slurry is soluble. The primary growth is generally larger than the re-growths. The quality of the primary growth is also better than that the re-growths. Use of slurry, if not digested and injected, at least tended to decrease the yield or protein content or protein yield of following cut or cuts or might increase the quality risks of silage and impact on the environment. The loss of yield is relatively and absolutely higher in the primary growth because of the use of slurry than in the re-growths. When non-digested slurry is used the loss in the total yield of season is smallest when the application takes place only after the 1st cut the ley still being able to use sol. N from slurry. The positive impact of digestion and injection after the 1st cut on the N utilisation is much greater than on the dry matter yield which empathise the positive environmental feature of those measures. Application only after the 2nd cut would be too late in that sense and mineral fertiliser should be used at that point. Digested slurry injected produces in this case comparable yields with mineral fertiliser. Because the primary growth is the largest and of the best quality it should be used for feed as the first option. The re-growths could then be used as a co-substrate in biogas reactors. Digested slurry is a good fertiliser for leys when injected. Injection of non-digested slurry reduces the ammonia emissions and leaching of soluble phosphorus but the significance of the low performance of nitrogen leaves open its fate. Slurry increases the hygiene risk and emissions of nitrous oxide just after the application but there are no differences in the hygiene between slurry and mineral fertilizer at harvest and the cumulative annual nitrous oxide emission.

References

BMU. 2007 Erfarungsbericht 2007 zum Erneuerbaren-Energien Gesetz (EEG) gemäβ § 20 EEG – BMU-Entwurf. Kurtzfassung. Bundesministerium für Umwelt, Naturschutz und Reactorsicherheit. pp. 43.

ETY. 1991. Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal L 375, 31/12/1991: 1- 8.

FME. 2002. National inventory report. Finland's report on the greenhouse gas emission inventory to the European commission. Common reporting formats (CRF): 1990 – 2001. Finnish Ministry of Environment. Available on the internet: http://www.ymparisto.fi/download.asp?contentid=5662&lan=EN

Goverment, 2000. Valtioneuvoston asetus maataloudesta peräisin olevien nitraattien vesiin pääsyn rajoittamisesta 931. Passed in Helsinki 9th November 2000.

Hagström, M., Vartiainen, E., Vanhanen, J., 2005. Biokaasun maatilatuotannon kannattavuusselvitys. Loppuraportti. pp. 77.
Huhtanen, P., Nousiainen, J., Rinne, M., 2006. Recent developments in forage evaluation with special reference to practical applications. Agricultural and Food Science 15: 293 – 323.
Huhtanen, P., Rinne, M., Nousiainen, J., 2007. Evaluation of the factors affecting silage intake of dairy cows: a revision of the relative silage dry-matter intake index. Animal 1: 758 – 770.
Kalmari, J., 2006. Maatilakohtaisen biokaasulaitosinvestoinnin kannattavuus suomalaisella sikatilalla. Helsingin yliopisto. Taloustieteen laitos. Selvityksiä nro 42: 1 – 70.
Kapuinen, P., 1994. Lannankäsittelyn taloudellisuuden ja lannan ravinteiden hyväksikäytön parantaminen. Agrifood Research Finland. Vakola Study Report 68: 1 – 90.
Mattila, P.K., Joki-Tokola. E., 2003. Effect of treatment and application technique of cattle slurry on its utilization by ley. I. Slurry properties and ammonia volatilization. Nutrient Cycling in Agroecosystems 65: 221-230.
Mattila, P.K., Joki-Tokola, E., Tanni, R., 2003. Effect of treatment and application technique of cattle slurry on its utilization by ley. II. Recovery of nitrogen and composition of herbage yield. Nutrient Cycling in Agroecosystems 65: 231-222.
MMM, 2007. Maa- ja metsätalousministeriön asetus maatalouden ympäristötuen perus- ja lisätoimenpiteistä ja maatalouden ympäristötuen erityistuista. Passed in Helsinki 26th April 2007.
MTT, 2006. The feed tables and feeding recommendation 2006. MTT:n selvityksiä 106: 1 - 84
Tyynelä, S, Kapuinen, P., Niemeläinen, O., 2004. Nurmien väkilannoituksen aiheuttamien ympäristöhaittojen vähentäminen sijoituslannoituksen avulla. In: Maataloustieteen Päivät 2004. Suomen Maataloustieteellisen Seuran Tiedote no 19. (Eds. Hopponen, A, Rinne, M.) Published 5.1.2004. Available on Internet http://www.smts.fi. ISBN 951-9041-47-8.